Rheological Characterization of Filtered Bauxite Residue

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Abstract

The need for an adequate understanding of tailings yielding and flow behavior has been the subject of rheological studies in the mining industry. In this context, hydrodynamic tailings studies incorporated advanced models better to represent the rheological phenomena of these materials on movement. Brazil is one of the leading ore processors of bauxite for alumina production and hence, the cradle of large bauxite residue disposal areas. Based on the development of residue disposal methodologies applied explicitly in the alumina industry, the rheological characterization is considered an important stage for a better understanding of residue behavior as a non-Newtonian fluid. This paper evaluates the applicability of rotational tests with a controlled shear rate regarding the rheological characterization of residue on a viscous basis. For this purpose, the paper describes the methodology applied to the beforementioned laboratory tests performed in the bauxite residue dewatered by drum filters. Undisturbed and disturbed samples were collected at different depths within the bauxite residue disposal area and tested over different moisture content conditions. Finally, based on the laboratory test results, the study evaluates the influence of the moisture content of samples on the flow and viscosity curves.

Keywords: Filtered bauxite residue, Rheological characterization.

1. Introduction

The tailing's yielding and flow understanding has been the subject of research involving the mining and industry sectors. To better understand the bauxite residue behavior and incorporate an advanced dam break model, Hydro Alunorte has investigated the bauxite residue disposal area DRS1. The bauxite residue disposal area of Hydro Alunorte started its operation in 1995 on a 270 hectares site. The refinery generates over 4 200 000 tonnes of bauxite residue annually, deposited in the two bauxite areas, the DRS1 and the recent expansion DRS2. The operations consisted of cyclical disposal, alternating the deposition to allow the residue paste to desiccate under solar incidence. The drum filter disposal methodology required large areas for natural drying and was withdrawn with the implementation of the press filter plant for bauxite residue filtration.

For most mineral residues, such as suspensions, pulps, or residue pastes, the proper understanding of the behavior regarding deformation and flow depends not only on the physical determination of the phenomena of elasticity and plasticity but also on the consideration of their viscous nature.

In this context, Hydro Alunorte performed a broad site investigation, collecting undisturbed and disturbed samples. The material was tested in the laboratory for geotechnical and rheological characterization to enhance the dam break studies developed for the site.

2. Material and Methods

The knowledge of the rheological properties of tailings and residues makes it possible to portray their crucial characteristics in flow and deformation, evaluating the influence of solids content on their flow and viscosity curves and the development of time-dependent phenomena [1].

There are two types of apparatus commonly used to measure the viscosity of materials: viscometers and rheometers. Viscometers are simple devices that measure viscosity as a function of velocity or shear rate controlled during the test. At the same time, rheometers are more sophisticated devices that allow other rheological tests – such as rotational, creep, relaxation, and oscillatory tests.

Within the scope of rheometry, both liquids and solids can be tested. Among the most common test equipment, there are rotational and oscillatory rheometers. Rotational tests are used to characterize the viscous behavior of the material [2]. On the other hand, creep, relaxation and oscillatory tests allow the investigation of the viscoelastic and time-dependent behavior.

The rotational test is used in this research to determine the viscous behavior of material from flow and viscosity curves, in addition to providing the yield stress (τ_y). The viscosity studied in rotational tests is called dynamic viscosity and is determined according to Equation (1) by the relationship between the shear stress and the shear rate.

$$\eta = \tau / \dot{\gamma} \tag{1}$$

where:

$\boldsymbol{\eta}$ Dynamic viscosity, Pa.s
$\boldsymbol{\tau}$ Shear stress, Pa
$\dot{\boldsymbol{\gamma}}$ Shear rate, s^{-1}

The rheological tests were performed in the laboratory LME (*Laboratório de Microestrutura e Ecoeficiência de Materiais*) of University of São Paulo and used a rotational rheometer with vane geometry to measure the bauxite residue stress-strain relationship. The test was performed in two phases. The first consisted of accelerating the strain rate from 0 to 70 s^{-1}, and the second was decelerating in inverse the strain rate to null. The acceleration cycle is related to the start of motion and static parameters, while the second cycle refers to the material rest and dynamic parameters. This method is known as the shear-flow test.

2.1 Sampling

Thirty samples were collected using push tube sampling at different depths and spatially distributed along 09 investigation isles, shown in Figure 1. The isles' location covered different moisture conditions, so the entire bauxite residue disposal area was investigated.

The location definition followed the criteria (i) prioritized areas where the drum filter residue had been more recently disposed; (ii) areas potentially mobilized in the dam break studies; (iii) depths with bauxite residue with higher moisture content.

Additionally, 20 l of supernatant effluent from DRS1 was collected and stored in a hermetically sealed recipient.

The topographic coordinates of the collection points were registered in SIRGAS2000 datum.

Finally, another relevant point to investigate is the manifestation of time-dependent phenomena for bauxite residues. A more complex non-Newtonian behavior associated with time-dependent phenomena is often observed in soils and mining tailings. Phenomena such as creep, thixotropy, or rheopectic occur from the realignment of material particles on a time scale. Investigating such phenomena through specific rheological tests and understanding the residue rheological parameters in rotational and oscillatory tests provide a broad and assertive understanding of the stress-strain-time behavior of a material.

4. Conclusions

Aiming to characterize the behavior of bauxite residue when exposed to excessive deformations by such a magnitude flow and structural changes manifest themselves, this study proposed the development of rotational rheological tests with a controlled shear rate for different conditions of moisture content.

The tests, carried out with samples collected in nine isles spread over a bauxite residue deposit filtered by a drum filter, were performed using a rotational vane rheometer in two cycles of loading and unloading up to a specified shear rate. Three distinct groups of samples were considered, amongst undisturbed and disturbed samples, molded under different solid contents. The main rheological parameters, yield stress, and viscosity were estimated using Bingham's mathematical model, applicable to fluids classified as plastic and pseudoplastic, as is the case of bauxite residue.

The yield stress and the viscosity analyzed presented an exponential growth, proportional to the increase in solids content. In other words, the decrease in the residue moisture content implied an increase in resistance for static and dynamic yield stresses. Furthermore, a dispersion of the residue parameters was evident in the solids content range above 68 %. This behavior may indicate that the material is in a transitional range, in which the purely viscous deformations no longer govern the phenomenon.

For future studies, rheological characterization of the bauxite residue should be complemented by oscillatory tests, providing characterization in terms of its viscoelastic nature. Such tests should evaluate in a more adherent way the moment of physical transition for this solid content range. Furthermore, characterization tests of time-dependent phenomena, such as creep, thixotropy, or rheopexy, may provide a more comprehensive and assertive understanding of the stress-strain-time behavior of the material.

5. References

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